Modeling Microwave Emission From Multi-layered Snowpacks Using Spectrally Derived Snow Grain Size

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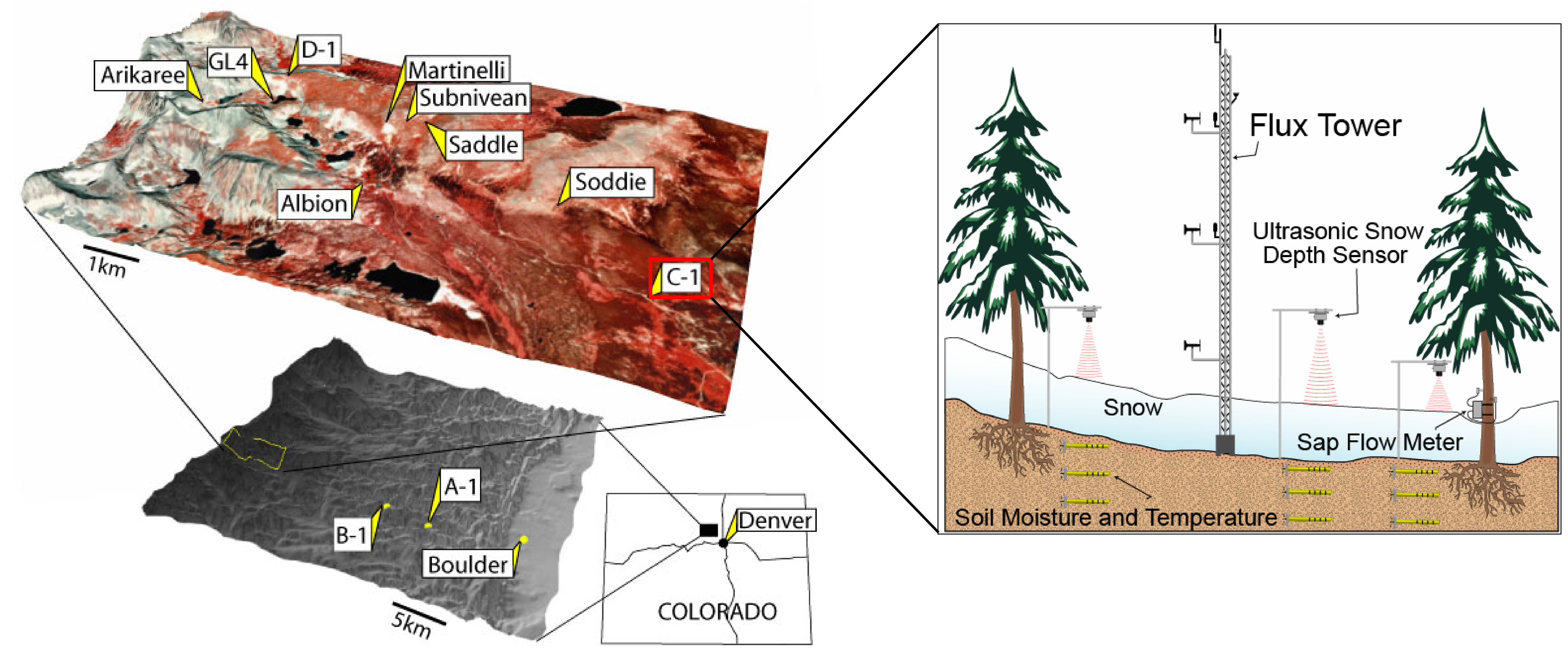
Introduction

Measurement of snow water equivalent (SWE) via passive microwave remote sensing measurements are impeded by the many-to-one relationships between brightness temperature and SWE which result from measurement sensitivity to snow grain size. Understanding of these relationships are limited, in part, by inadequate in situ snow grain size measurement capabilities. To address this problem we have developed optical techniques for measuring snow grain radius which can be physically related to grain correlation length; which controls the radiometric response of snow for microwave frequencies (Mätzler and Wiesmann, 1999). We test this new approach in forested regions which represent a large percentage of seasonally snow covered areas. In this regard, we evaluate relationships between vegetation structure, snow grain size, and microwave emission. Field spectroscopy combined with contact illumination was used to make spatially continuous (both vertical and horizontal) observations of snow grain size. In addition, we illustrate how these measurements can be combined with direct observations of hydrologic states to fully characterize snowpack microwave emission. The following questions are addressed:

1) what is the horizontal and vertical variability of snow grain size within multi-layered snowpacks?
2) how does vegetation impact variability in snow grain size?
3) how sensitive is snowpack microwave emission to variability in snow grain size?

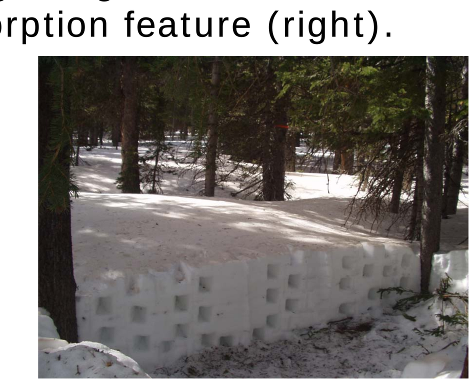


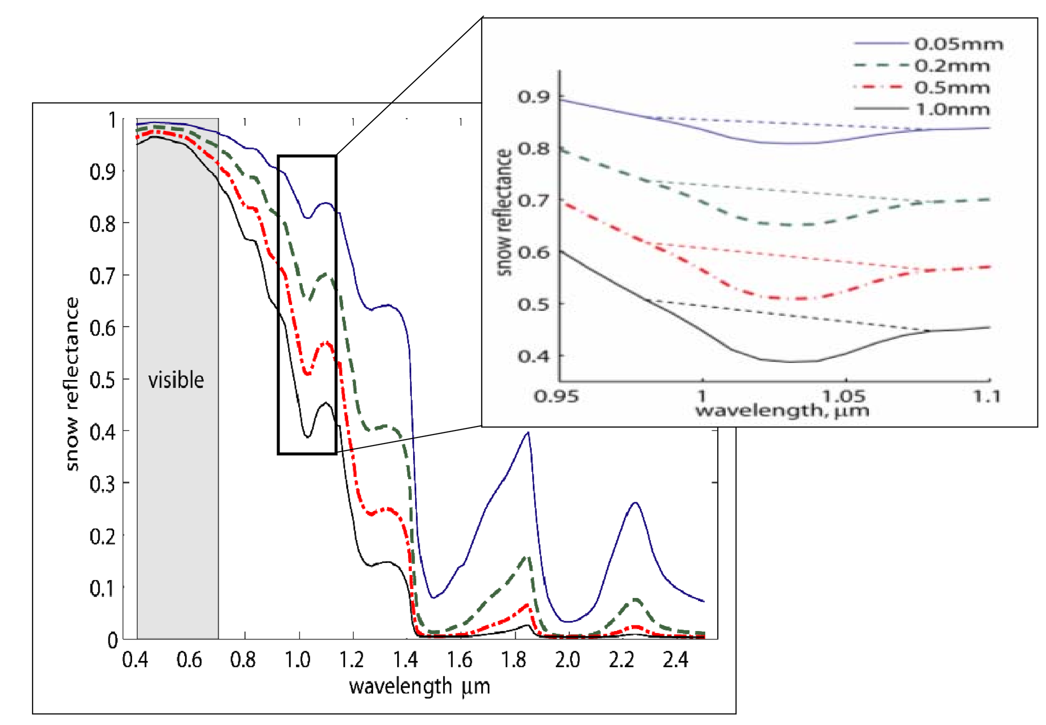
Methods

Trenches were excavated extending radially from tree trunks.

Snow grain size was measured at 6 cm sampling interval using an ASD-Field Spectroradiometer.

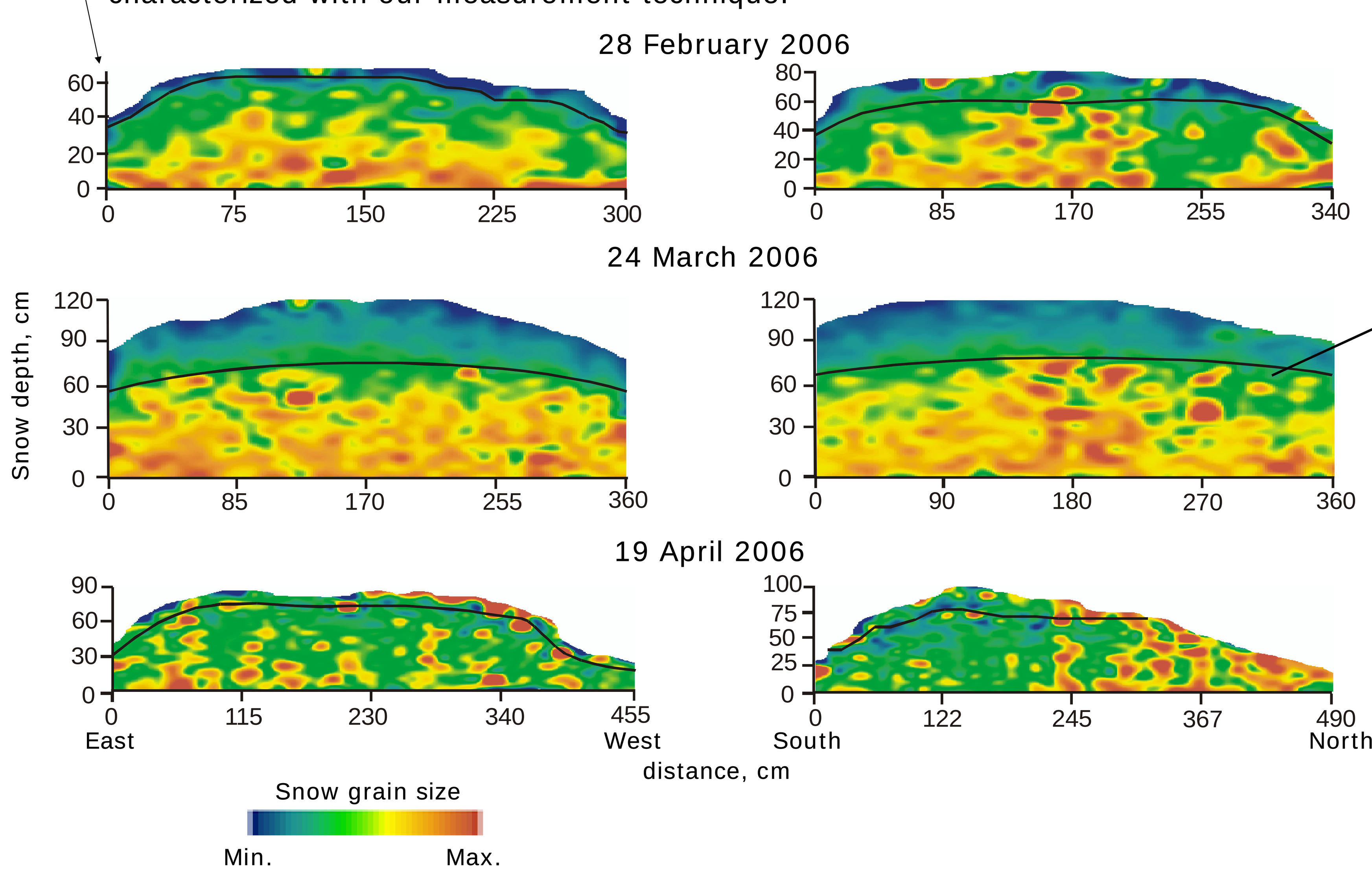
Snow grain size was determined by integrating the area of the 1030 nm ice absorption feature (right).





Snow Grain Size

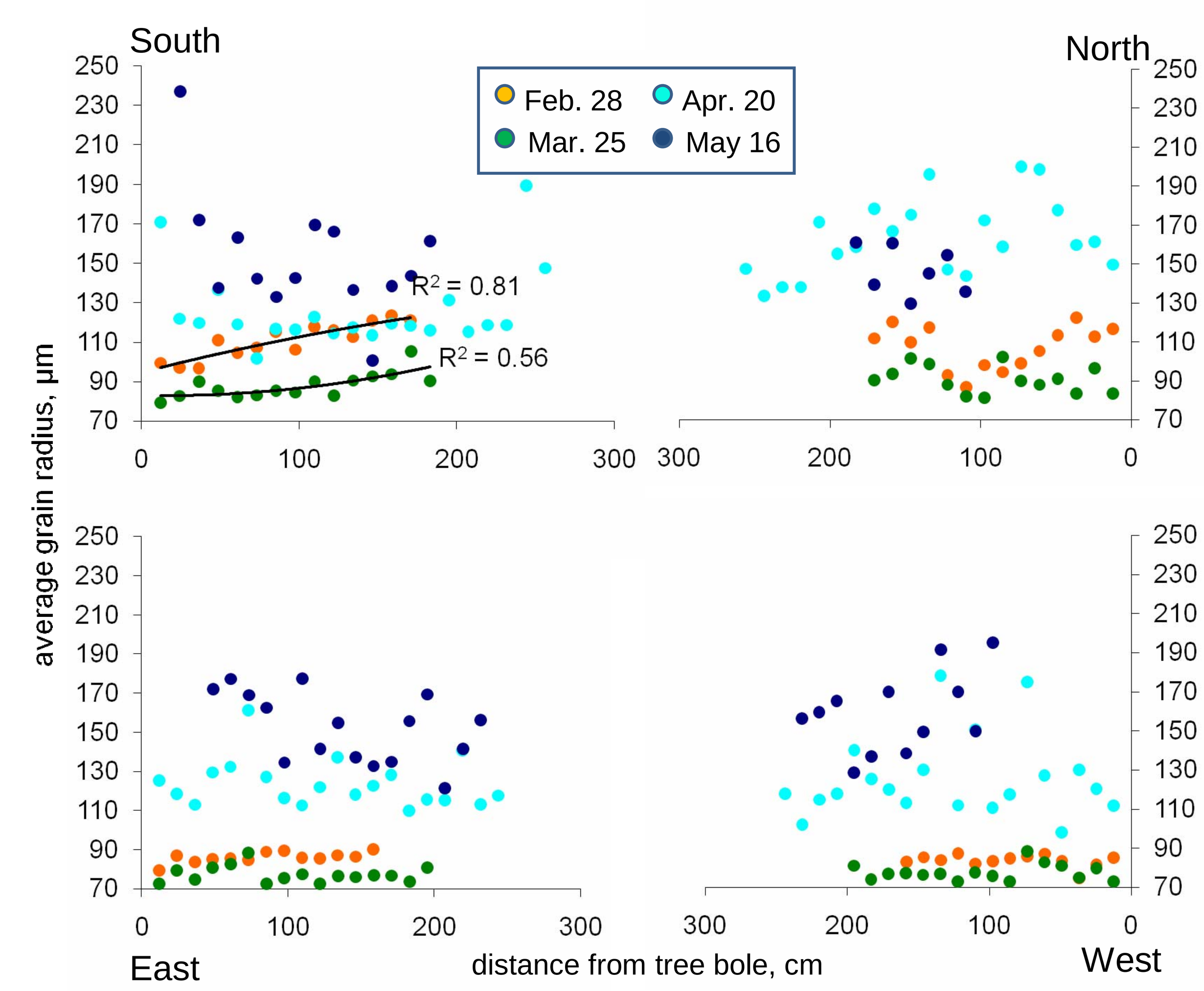
General trends in snow grain size were well characterized with our measurement technique.



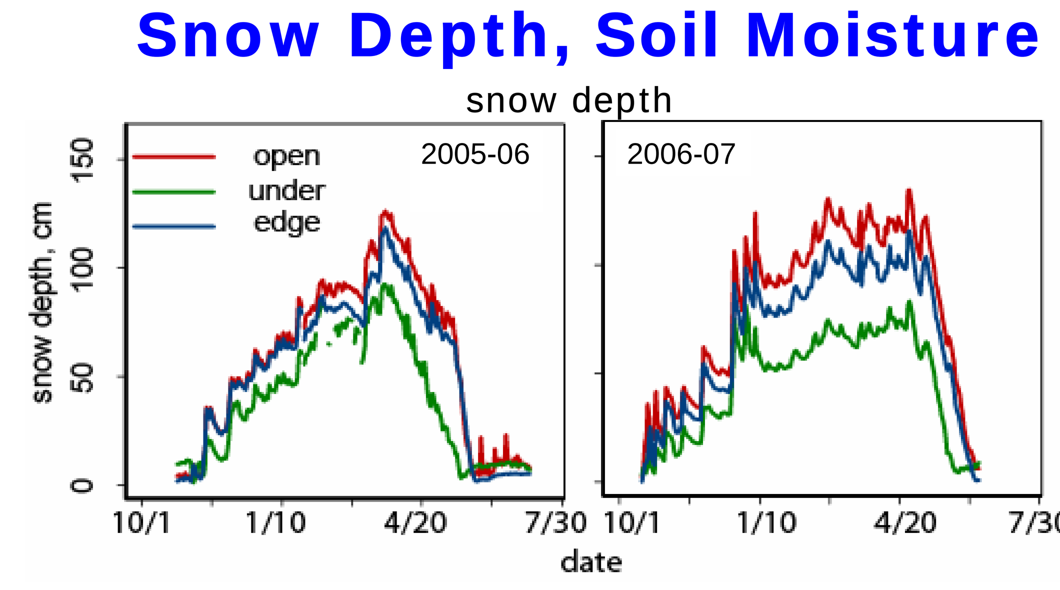
A distinct boundary between round and faceted snow grains coincided with buried dust layer.

Horizontal variability in snowpack stratigraphy was strongly influenced by surface properties.

Vertically-averaged grain size increased during snowmelt. Relationships between grain size and tree-bole distance were statistically significant on the north side of trees.

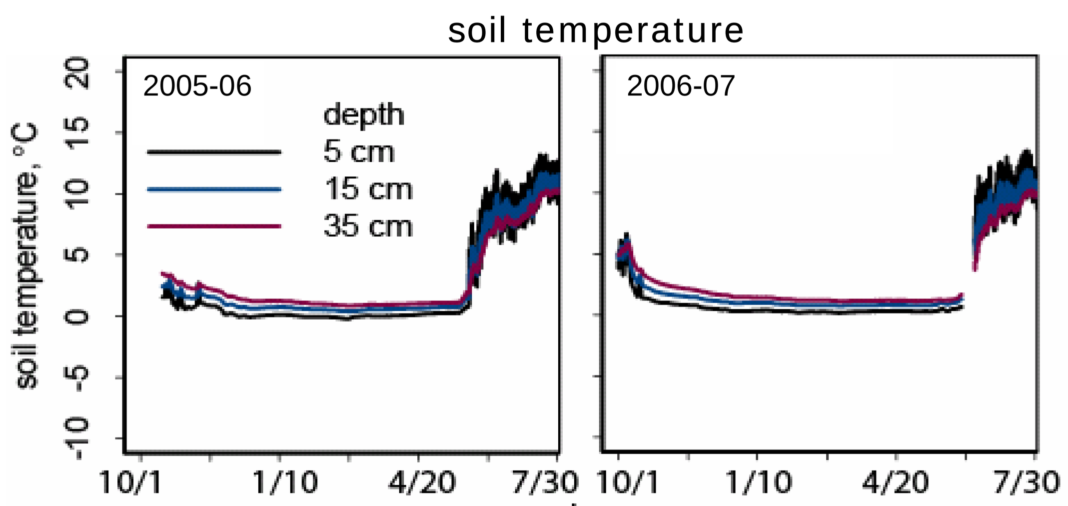


Snow Depth, Soil Moisture & Temperature



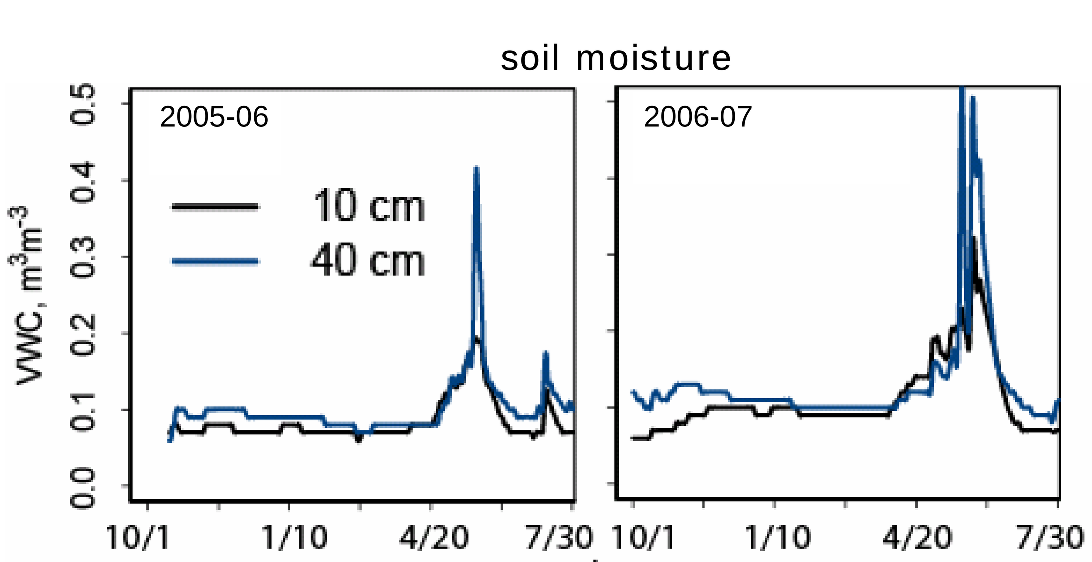
Snow accumulatoin was 33% greater in open vs under canopy locations.

Snow ablation rates were 30% greater in open areas indicating more rapid snow metamorphosis.



Soil temperatures were inversely correlated with air temperatures due to snowpack insulation of soil.

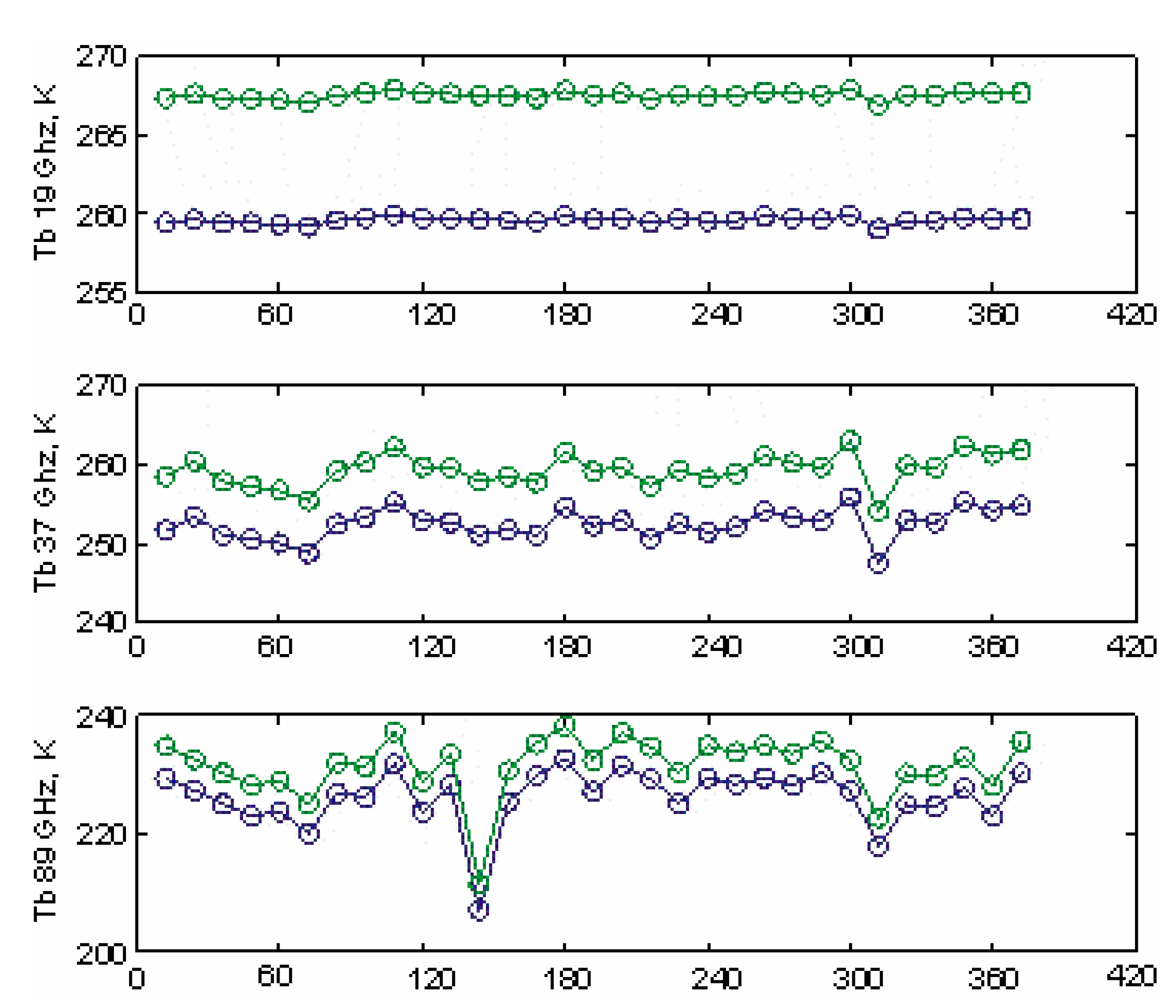
Soil temperatures remained near freezing level throughout winter season.



Snowmelt infiltration lagged spring onset by 12 days indicating considerable cold content.

Peak soil moisture occurred within 4 days of snow disappearance.

Microwave Emission



Simulations of microwave emission using the Microwave Emission Model of Layered Snowpacks (MEMLS) (Wiesmann & Matzler, 1999; Matzler & Wiesmann; 1999) indicated that snowpack microwave emission was highly sensitive to effective grain size at 37 and 89 Ghz.

Variability in snow grain size across snow trenches introduced up to 10 K variability in brightness temperature at 37 Ghz.

Similar effects were seen at 89 Ghz were differences in grain size associated with vegetation structure introduced as much as 35 K variability in brightness temperatures.

Conclusions

Vegetation structure introduced considerable variability in the timing and magnitude of snow accumulation, snow melt, and vertical and horizontal variability in snow properties. The use of field spectroscopy combined with contact illumination represents a repeatable and quantitatively consist manner of observing these controls. These observations provide a useful means to constrain forward models of snowpack evolution and for simulating microwave emission from layered snowpacks. Future efforts will include collocating these new in situ measurements with ground-based and airborne radiometers.

References: Wiesmann A., and C. Mätzler, "Microwave emission model of layered snowpacks", Remote Sensing of Environment, Vol. 70, No. 3, pp. 307-316 (1999); Mätzler C. and A. Wiesmann, "Extension of the Microwave Emission Model of Layered Snowpacks to Coarse-Grained Snow", Remote Sensing of Environment, Vol. 70, No. 3, pp. 317-325 (1999).

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